

ISL75052SEH

Single-Event Performance

AN1851

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Introduction

The intense proton and heavy ion environment encountered in space applications can cause a variety of Single-Event Effects (SEE) in electronic circuitry, including Single-Event Upset (SEU), Single-Event Transient (SET), Single-Event Functional Interrupt (SEFI), Single-Event Latch-up (SEL), Single-Event Burnout (SEB) and Single-Event Gate Rupture (SEGR). SEE can lead to system-level performance issues including disruption, degradation and destruction. For predictable and reliable space system operation, individual electronic components should be characterized to determine their SEE response.

This report discusses the results of Intersil's SEE testing of the ISL75052SEH LDO. Testing was carried out with two objectives in mind. The first was to establish safe operating limits with regard to input voltage and incident ion linear energy transport (LET). The second was to establish the characteristics of SET under normal operating conditions.

Note: Throughout this document LET_{EFF} is used to indicate effective linear energy transfer in units of $MeV \cdot cm^2/mg$. For brevity the units are omitted and should be understood throughout the rest of the document.

Executive Summary of Results

Damaging SEE (SEB, SEGR, or SEL)

No damage was recorded for parts tested at $V_{IN} \leq 15.0V$, $LET_{EFF} = 86$ (Au at normal incidence), and case temperature at $+125^\circ C \pm 10^\circ C$. Parts were tested both disabled (i.e. $V_{OUT} = 0.0V$) and with $V_{OUT} = 14.0V$ and $I_{OUT} = 1.8A$.

Single-Event Functional Interrupt (SEFI)

No SEFI were observed during any of the testing, and no SET on power-good (PG) to a 0.5V trigger was captured either.

Single-Event Transient (SET)

No V_{OUT} SETs were observed in excess of a V_{OUT} deviation window of +35mV and -20mV.

No power-good (PG) SET were found for an observational threshold of 0.5V.

The output capacitance was composed of two tantalum capacitors (T541X107M025AH6510) with nominal values of 100 μF and 60m Ω ESR.

Part Description

The ISL75052SEH is a radiation hardened, single output LDO specified for a maximum output current of 1.5A. The device is specified to operate from input voltages over the 4.0V to 13.2V range. Attainable output voltages are bounded by a 0.6V reference on the low end and a 225mV dropout at 1.5A or 75mV at 0.5A. The output is adjustable based on an external resistor divider. The 16-lead dual in-line ceramic flatpack has a metal pad on the bottom to facilitate thermal management. The part has an enable input (EN) and an open-drain power-good (PG) signal.

Irradiation Test Facility

Testing was performed at the Radiation Effects Facility of Texas A&M University's (TAMU) Cyclotron Institute in College Station, Texas. The TAMU facility is coupled to a K500 super-conducting cyclotron, which is capable of generating a wide range of ion species with the various energy, flux and fluence levels needed for SEE testing. Details about the facility and the ion beams can be found on the TAMU Cyclotron Institute web site (<http://cyclotron.tamu.edu/ref/>). The testing reported here was done March 7, 2013.

Reference Documents

- [ISL75052SEH](#) Datasheet
- [ISL75052SEH](#) Evaluation Board User Guide
- [ISL75052SEH](#) Radiation Test Report
- SMD ([5962-13220](#))

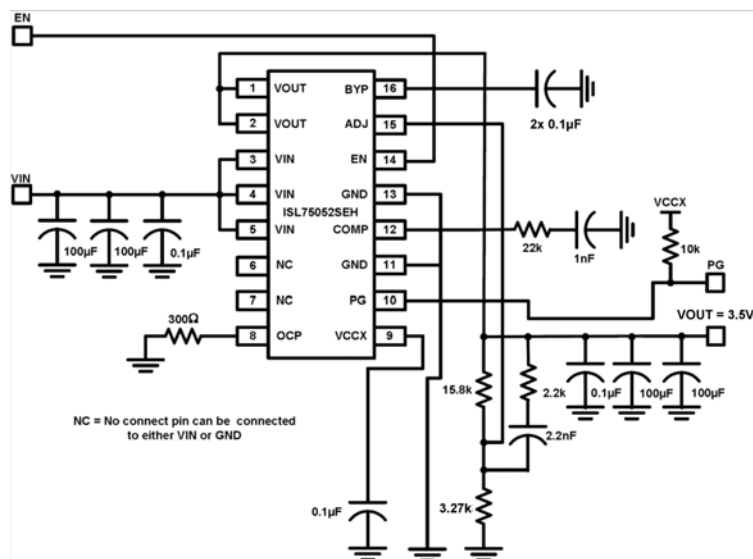


FIGURE 1. SCHEMATIC USED FOR SEE TESTING

SEE Testing Description

SEE testing was carried out with samples mounted on the engineering evaluation boards. Loading was provided by an electronic load. The schematic of the board is shown in [Figure 1](#).

Digital multimeters monitored input voltage (V_{IN}), output voltage (V_{OUT}) and input current (I_{IN}). In disabled test cases the leakage current to the output (ILK) was monitored. For damaging SEE (SEB, SEGR, SEL) studies the parts were heated with a film heater on the back of the circuit board to $+125^{\circ}\text{C} \pm 10^{\circ}\text{C}$ case temperature. The heater current to achieve the desired case temperature was determined prior to the TAMU trip and applied during testing. Parameters V_{OUT} , I_{IN} and ILK were monitored before and after irradiation as indications of part damage. For the SET studies the case temperature was left to ambient. V_{OUT} and PG (power-good) were used as the triggering signal for a LeCroy wave Runner 4-channel digital oscilloscope to capture SET. Other channels that were simultaneously captured the reference voltage (BYP), and the parts internally generated low voltage supply (VCCX).

Damaging SEE Testing and Results (SEB, SEGR, SEL)

The test matrix run for damaging SEE on the ISL75052 appears in [Table 1](#). The same four parts (device under test, DUT) were used for all the testing and accumulated about 55krad(Si) by the end of the testing. The parameters monitored pre and post irradiation to look for damage are listed with the actual measurements. The measurement variations are all within the on-site measurement repeatability so there is no evidence of damage. $V_{IN} = 14.7\text{V}$ was the intended goal for passing SEE without damage, while the $V_{IN} = 15.0\text{V}$ was an effort to document some margin against that goal.

TABLE 1. DAMAGING SEE TESTING MATRIX

UNIT	V _{IN} (V)	I _{OUT} (A)	V _{OUT} (V)		I _{IN} (mA) I _{OUT} = 0		ILK (nA) V _{OUT} = 0	
			PRE	POST	PRE	POST	PRE	POST
DUT1	14.7	Disabled			9.5	9.5	200	200
	14.7	1.8	14.011	14.012	24.8	24.6		
	15.0	Disabled			9.7	9.8	270	255
	15.0	1.8	14.011	14.012	24.7	24.8		
DUT2	14.7	Disabled			9.5	9.5	260	260
	14.7	1.8	13.978	13.980	24.1	24.2		
	15.0	Disabled			9.7	9.8	290	280
	15.0	1.8	13.980	13.979	24.4	24.3		
DUT3	14.7	Disabled			9.5	9.5	260	260
	14.7	1.8	13.973	13.975	23.9	23.7		
	15.0	Disabled			9.7	9.8	325	332
	15.0	1.8	13.969	13.969	24.2	24.1		
DUT4	14.7	Disabled			9.5	9.5	330	330
	14.7	1.8	14.040	14.040	24.0	24.0		
	15.0	Disabled			9.7	9.7	365	350
	15.0	1.8	14.051	14.051	24.3	24.1		

NOTE: Each of the 16 tests listed was done with Au at 0° (LET_{EFF} = 86), T_C = +125°C, and flux of 5x10⁴ ion*cm⁻²*s⁻¹ to fluence of 1x10⁷ ion/cm².

Damaging SEE (SEB, SEGR, SEL) Discussion

Conservatively the data in [Table 1](#) represents a fluence of 8×10^7 ion/cm² at V_{IN} 14.7V and $LET_{EFF} = 86$ without a failure. This corresponds to a nominal cross section of 1.25×10^{-8} cm², which is smaller than any active device in the product and so is a very strong statement against damage susceptibility at $LET_{EFF} = 86$. The clean results at $V_{IN} = 15.0V$ provide evidence of extra margin against the 14.7V product claim for SEB, SEGR, and SEL free operation.

SET Testing and Results

SET testing was done with gold (Au) at zero degrees incidence for $LET_{EFF} = 86$. The device temperature was left to the ambient conditions. The output voltage (V_{OUT}) was set to 3.5V for all tests. Four units were tested with irradiation runs at each of three different conditions: $V_{IN} = 4.0V$ and $I_{OUT} = 0.1A$, $V_{IN} = 4.0V$ and $I_{OUT} = 1.5A$, and $V_{IN} = 13.2V$ and $I_{OUT} = 0.1A$. The first two conditions cover a load range for low supply headroom (0.5V between V_{IN} and V_{OUT}) and the last condition looks at high supply headroom (9.7V). In the last case, the current was only tested at 0.1A because of thermal considerations. It was anticipated that the high load current and low headroom condition (nearest drop-out) would be the worst case for negative transients, and the low load current and high headroom case would be the worst for positive transients. This was indeed found to be the case.

Oscilloscope triggering on V_{OUT} was set to capture transients with $\pm 10mV$ V_{OUT} deviations and also $\pm 75mV$ V_{OUT} deviations. The BYP and VCCX were also captured on any V_{OUT} trigger for information on the origin of the SET. The captures were set to start 20 μs prior to the trigger and end 80 μs after the trigger.

No SETs were captured with the $\pm 75mV$ trigger during 1×10^7 ion/cm² of each run. The $\pm 10mV$ transients were plentiful; capturing was terminated at roughly 200 SET captures for each run. The 200 SET count limit was reached at about 2×10^6

ion/cm² for $I_{OUT} = 0.1A$, but was reached at about 1.3×10^6 ion/cm² for the 1.5A load. This reflects the generation of negative transients achieving the trigger value with the higher load current (1.5A); the same SET at the lower load current (0.1A) did not reach the trigger value and so were not captured.

No SET on PG (power-good, to a -0.5V trigger) was registered.

TABLE 2. SUMMARY OF V_{OUT} SET TESTING

RUN	DUT	V_{IN}	I_{OUT}	COUNT	TERMINATING FLUENCE
421	1	4.0	0.1	201	1.92E+06
424	2			200	1.88E+06
427	3			202	1.96E+06
430	4			202	2.02E+06
422	1		1.5	202	1.22E+06
425	2			202	1.18E+06
428	3			206	8.66E+05
431	4			272	1.54E+06
423	1	13.2	0.1	201	2.22E+06
426	2			202	1.89E+06
429	3			202	1.90E+06
432	4			202	1.52E+06

SET Composite Plots and Discussion

The following plots give a qualitative look at the SET populations captured. For each of the three operating conditions tests has a plot for each of the four DUTs. These plots are composites of the first 200.

Composite Plots

All SET captured for each DUT at $V_{IN} = 4.0V$, $V_{OUT} = 3.5V$, $I_{OUT} = 0.1A$. Time (abscissa) is 10 μs /div and V_{OUT} (ordinate) is 10mV/div.

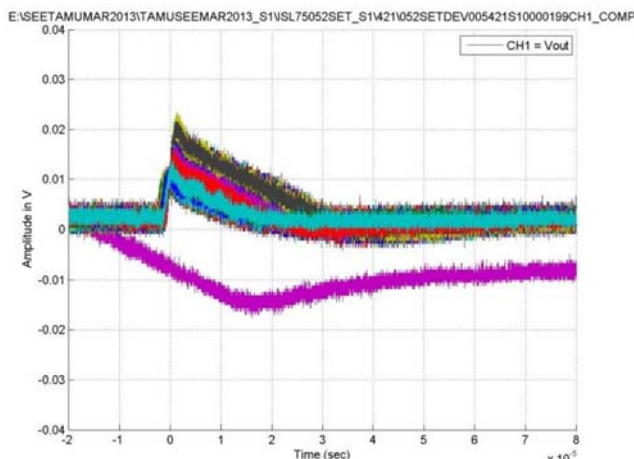


FIGURE 2. DUT1

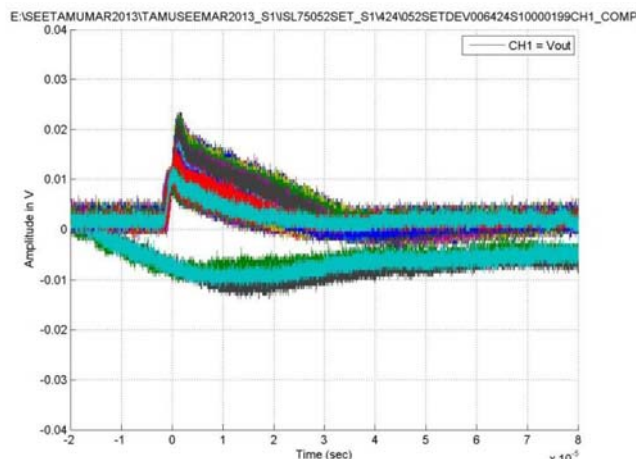


FIGURE 3. DUT2

Composite Plots

All SET captured for each DUT at $V_{IN} = 4.0V$, $V_{OUT} = 3.5V$, $I_{OUT} = 0.1A$. Time (abscissa) is $10\mu s/div$ and V_{OUT} (ordinate) is $10mV/div$. (Continued)

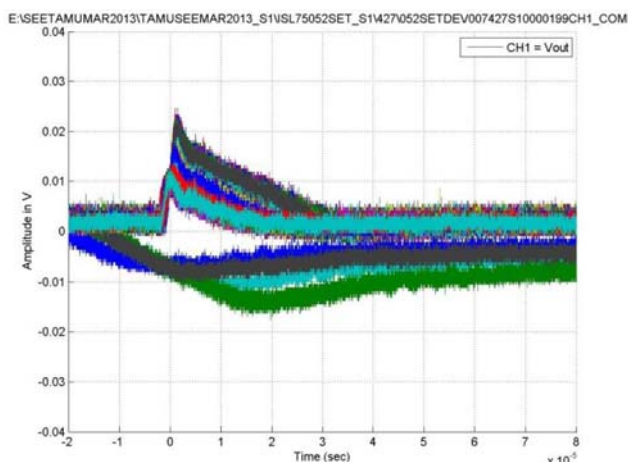


FIGURE 4. DUT3

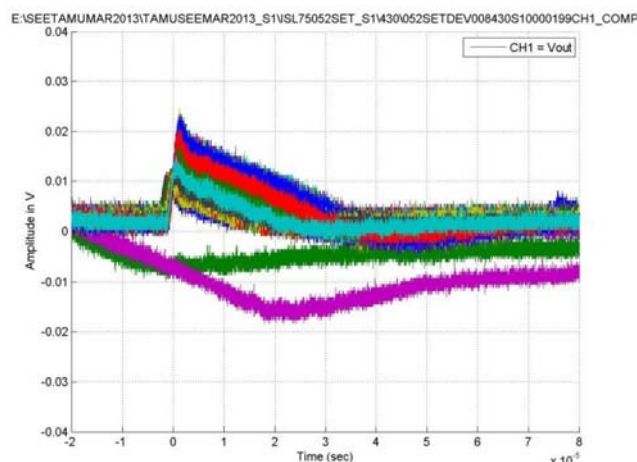


FIGURE 5. DUT4

The vast majority of the SET for $V_{IN} = 4.0V$ and $I_{OUT} = 0.1A$ are fast, positive transients indicating a rapid increase in the current being supplied by the ISL75052SEH beyond the load demand ($0.1A$). The fast, positive transients peak about $2\mu s$ to $3\mu s$ after they start with a small spike at the top. The small spike at top of the SET is due to the excess current encountering the high frequency impedance of C_{OUT} . The falling edge of this spike indicates the real SET is over in less than $5\mu s$. However, C_{OUT} has been overcharged in that time so that V_{OUT} is now above the setting. Since the ISL75052 has no active pull-down device, the excess V_{OUT} can only decay away through the load and feedback divider. The $0.1A$ load and the C_{OUT} value then set the rate of decay of the V_{OUT} overvoltage ($200\mu F$ at $0.1A$ for $0.5mV/\mu s$ or $5mV/div$ in the figures).

The few slow, negative transients begin with the characteristic discharge rate of C_{OUT} indicating the part has stopped supplying current. A bottom V_{OUT} is reached above $-20mV$ at which time the parts supply of current resumes. A relatively slow ($100s$ of μs) recovery back to the nominal V_{OUT} ensues. These slow, negative V_{OUT} transients correlated to small drops in the reference voltage (BYP) used for regulation. The entire V_{OUT} SET can then be understood on the basis of a slight dropping of BYP due to the ion. For the $-20mV$ events seen here at $V_{OUT} = 3.5V$, the driving SET deviation in BYP is only about $-3mV$.

All the captured transients in [Figures 6 through 9](#) are bounded by a window of $+25mV$ and $-20mV$ deviation. These correspond to $+1\%$ and -0.6% of the $3.5V$ output. At lower output voltages the absolute magnitudes would be expected to apply; for a $1V$ output the relative deviations would become $+3.5\%$ and -2% .

Composite Plots

100 SET captured for each of DUTs 1 through 4 at $V_{IN} = 4.0V$, $V_{OUT} = 3.5V$, $I_{OUT} = 1.5A$. Time (abscissa) is $10\mu s/div$ and V_{OUT} (ordinate) is $10mV/div$.

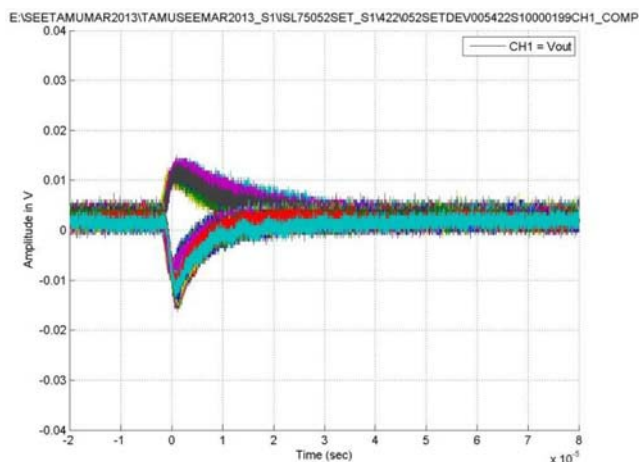


FIGURE 6. DUT1

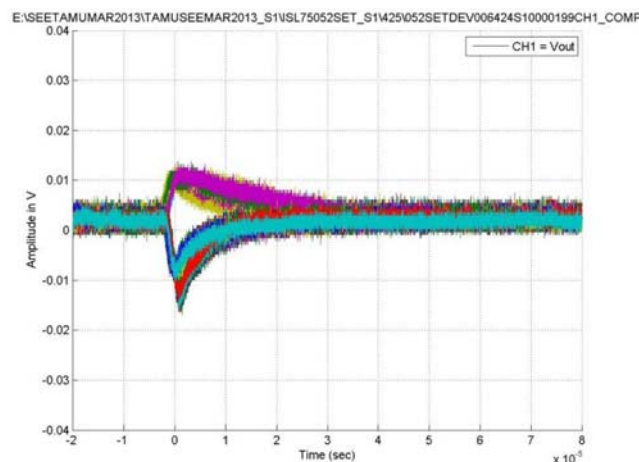


FIGURE 7. DUT2

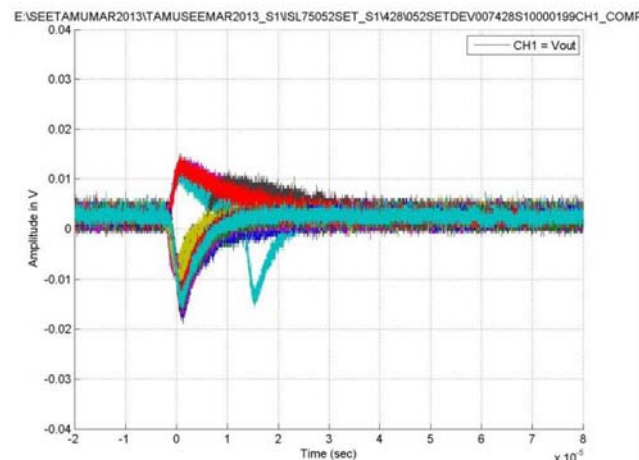


FIGURE 8. DUT3

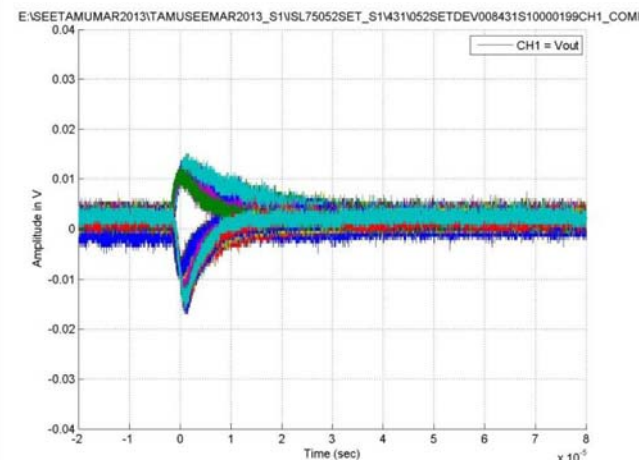


FIGURE 9. DUT4

With 1.5A of load current, the dominant form of SET captured switched to a fast, negative transient. The high loading draws V_{OUT} down rapidly now when the device current being supplied is interrupted. At the lower load (0.1A) the same SET would not have resulted in a V_{OUT} drop large enough to reach the 10mV trigger. So it is not that any new SET form has appeared, it is just that the SET are amplified by the higher load to the point of capture. The fast, negative transients have a duration of only a few microseconds (the precipitous fall in V_{OUT} set by the load current). Then the loop control recovers V_{OUT} in about 20 μs .

There are still some fast, positive transients. These are actually the same transients seen in [Figures 10](#) through [13](#), but the higher load demand has modified the captured forms a bit. The rise is not quite as fast and the spike at the top is gone. This is an indication that the charging of C_{OUT} is much reduced; this is also supported by the lower V_{OUT} ramp starts.

There were no slow, negative transients observed. There is no obvious reason for this to be the case. However, given the correlation to the BYP disturbances, there is no reason to believe

that similar BYP events would look significantly different from those in [Figures 10](#) through [13](#) other than a more rapid decline followed by the same slow recovery.

These captured transients for $I_{OUT} = 1.5A$ are bounded by +15mV and -20mV. This is less in both directions than the previous case.

Composite Plots

200 SET captured for each of DUTs 1 through 4 at $V_{IN} = 13.2V$, $V_{OUT} = 3.5V$, $I_{OUT} = 0.1A$. Time (abscissa) is $10\mu s/div$ and V_{OUT} (ordinate) is $10mV/div$.

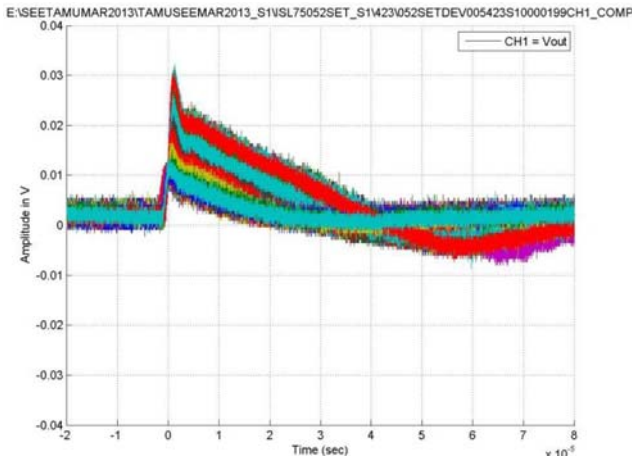


FIGURE 10. DUT1

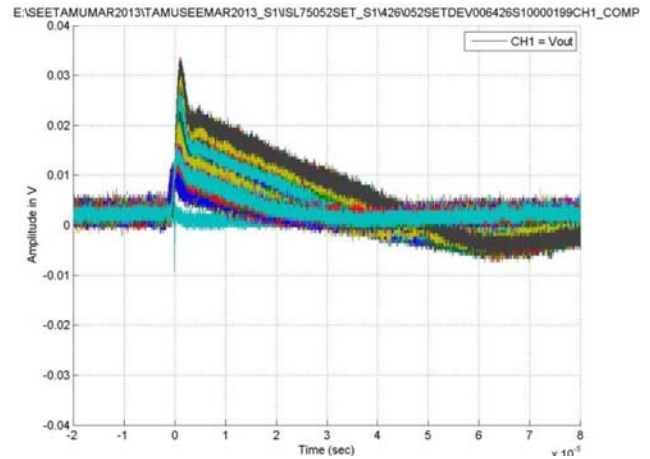


FIGURE 11. DUT2

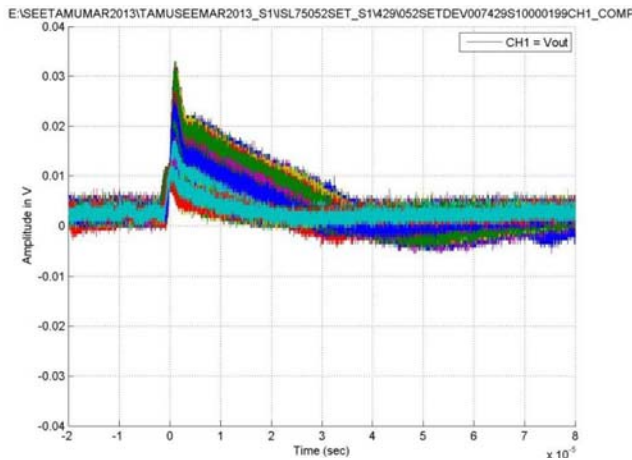


FIGURE 12. DUT3

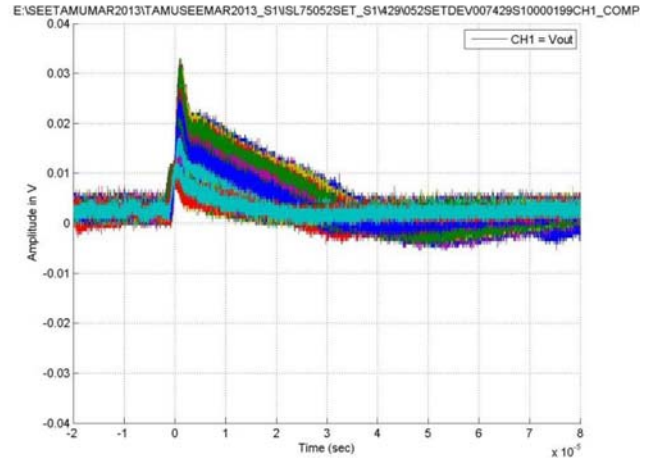


FIGURE 13. DUT4

For the case of $V_{IN} = 13.2V$ and $I_{OUT} = 0.1A$ the fast, positive transients again dominate as they did in [Figures 2](#) through [5](#) ($V_{IN} = 4.0V$, $I_{OUT} = 0.1A$). However, with more V_{IN} headroom (9.7V above V_{OUT}) both the spike at the top of the SET and the residual charging of C_{OUT} are larger. This indicates that more current is being pushed during the SET. Clearly the worst case positive SET are found for low load currents and high headroom on V_{IN} .

There is still one slow, negative transient that correlates to a minuscule drop in BYP .

Under these conditions the transients are bounded by +35mV and -15mV. Over all three operational conditions the observed transients are bounded by a +35mV and -20mV window.

Further SET Discussion

No SEFIs, PG SETs, or V_{OUT} SETs in excess of $\pm 75mV$ were observed to the full 1×10^7 ion/cm² in each of the 12 SET runs (4 DUTs, 3 conditions). This puts rather comfortable bounds on any possible cross section for events. At the very least, 4×10^7 ion/cm² failed to generate these events for each of the three operating conditions. Taken together, a fluence of 1.2×10^8 ion/cm² yielded no events.

A MATLAB program was applied to the SET data to extract the peak deviation and the time duration outside the $\pm 10mV$ deviation window. The deviations were calculated based on the V_{OUT} of that trace prior to triggering, so there is a small offset from the absolute scales of the SET plots. The results are plotted in [Figure 14](#). This clearly shows a SET deviation window (+33mV, -20mV) and highlights two types of SET. Most SETs are a short disturbance followed by a recovery time that depends on the loading conditions. At light loading (0.1A) the positive SET are larger and require time to discharge C_{OUT} . At high loading (1.5A) negative SET dominate due to interruption in current, and the recovery proceeds immediately after that SET when control loop reasserts itself and supplies recovery current. The long negative SET are due to small drops in the reference voltage and require a longer time to recover.

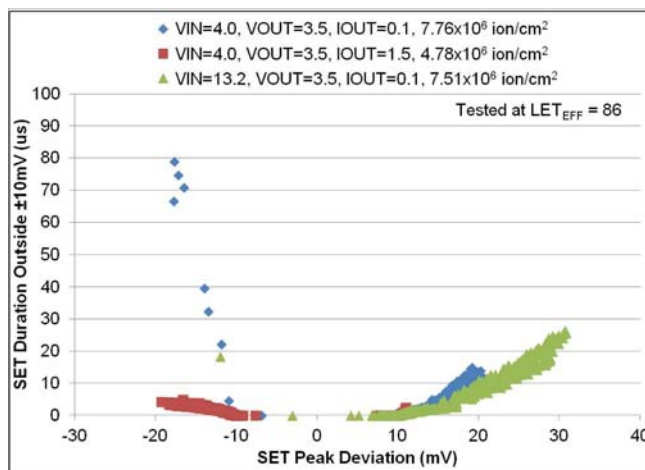


FIGURE 14. SET DURATION VERSUS SET PEAK DEVIATION FOR ALL CAPTURED DATA

Another way to look at the SET population is to consider the cross section presented by the various SET magnitudes. This approach yields the plot in [Figure 15](#). The small population of long, negative SET so obvious in [Figure 14](#) corresponds to the very small cross section negative events in [Figure 15](#).

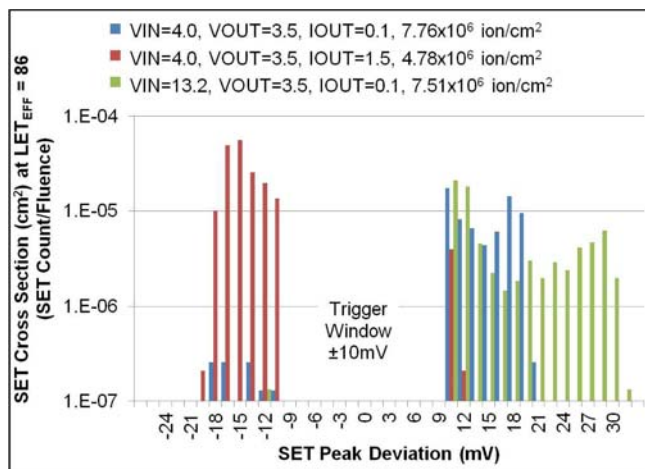


FIGURE 15. SET REPRESENTED AS CROSS SECTION BY EVENT V_{OUT} PEAK DEVIATION

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